

Development of an Ultra-Low NO_x Integrated System for Pulverized Coal Fired Power Plants

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Summary

Overview

ALSTOM Power, Inc. has developed an Ultra-Low NO_x Integrated System for Coal Fired Power Plants under a Cooperative Agreement with the U.S. DOE. The system builds on ALSTOM Power's field-proven TFS 2000TM low NO_x firing system to achieve furnace outlet NO_x emissions at or below 0.15 lb/MMBtu for existing tangentially fired boilers firing a range of high volatile coals.

The integrated system development project included characterization of 3 fuels in US Power Plant Laboratory's (USPPL) Drop Tube Furnace System (DTFS), computational fluid dynamics (CFD) modeling, and large pilot-scale testing in USPPL's 17.5 MW_t Boiler Simulation Facility (BSF). An engineering and economic analysis of 3 utility boilers was also performed to compare the cost of available NO_x reduction strategies including firing system modifications, fuel switching to Powder River Basin (PRB) coals, and SCR.

The foundation for the Ultra-Low NO_x Integrated System is ALSTOM's field-proven TFS 2000TM low NO_x firing. The integrated system achieves further reductions in NO_x emissions by enhancing current system components, optimizing fuel and air distributions, incorporating advanced sensor and control technology, and adding post combustion control measures as needed for a particular unit and fuel. Specific system enhancements / variables that were studied include the effect of transport air:fuel ratio, coal and airflow balancing, configuration of windbox auxiliary air compartments, overfire air location and velocity, and improved coal fineness.

An advanced neural net control system was evaluated as a means to maintain target NO_x emissions by controlling both local and global stoichiometries over the range of boiler operating loads. The advanced control system helps diagnose the combustion process through existing instrumentation and employs advanced sensor technology including coal mass flow measurements in each fuel transport line and advanced flame scanners at each fuel nozzle. Collectively, the advanced control components should help to provide optimum system performance across a range of input parameter variations.

Fuels Characterization

Three coals were used in the development of the Ultra-Low NO_x Integrated System, a sub-bituminous coal from the Powder River Basin (PRB), a high volatile bituminous (hvb) coal from the Midwestern U.S. , and a medium volatile bituminous (mvb) coal from the Eastern U.S. Each of coals was characterized using both ASTM and DTFS testing. The ASTM results were consistent with expectations as a function of coal rank.

Pyrolysis experiments were run in the DTFS to measure the “high temperature” volatile matter (VM) yield of the coals. Combustion experiments were also performed in an argon-oxygen environment to look at the evolution of nitrogen from the coals as a function of stoichiometry. The PRB coal released nitrogen at the same rate as the carbon was consumed, while the hvb coal released nitrogen from the coal more rapidly than carbon. The nitrogen release from the mvb coal occurred more slowly than the carbon conversion, resulting in increased levels of nitrogen in the char. The increased char nitrogen when firing the mvb coal will result in higher NO_x emissions as char nitrogen is more readily oxidized than nitrogen associated with the volatiles.

CFD Modeling

Overfire air mixing has a significant impact on the combustion efficiency and can limit the ultimate NO_x level achieved in a utility boiler. Often the excess air must be increased or the quantity of overfire air decreased to obtain acceptable CO and carbon in ash levels, resulting in higher NO_x emissions. The CFD modeling effort attempted to quantify the degree of mixing of the overfire air and its impact on combustion efficiency to order to improve the performance of the overfire air system. Variables examined in the modeling study include the overfire air configuration (including location and velocity), coal particle trajectories (firing angle), and underfire air.

Combustion Testing

Large pilot-scale demonstration of the components of the Ultra-Low NO_x Integrated System for Coal Fired Power was performed in ALSTOM’s Boiler Simulation Facility (BSF). Combustion tests were performed for the 3 coals over the range of 30-60 MMBtu/h to quantify the impact of the proposed system improvements on NO_x emissions.

Baseline NO_x emissions increased with coal rank 0.49, 0.56, and 0.66 lb/MMBtu for the PRB, hvb, and mvb coals, respectively. The optimized TFS 2000TM firing system achieved NO_x emissions of 0.11, 0.15, and 0.22 lb/MMBtu for the 3 fuels for approximately 70-75% reduction over the baseline NO_x emissions. Additional NO_x reduction of approximately 0.03 lb/MMBtu over the optimized TFS 2000TM levels was achieved using the Ultra-Low NO_x firing system technology.

For the PRB fuel, the low NO_x firing system technologies had little impact on the unburned carbon levels which were always less than 0.1% carbon in the fly ash. As expected, the quantity of unburned carbon in the fly ash for the baseline tests increased with coal rank. The carbon in the fly ash increased under low NO_x firing conditions for the bituminous coals. The additional NO_x reduction achieved with the Ultra-Low NO_x System components came at the expense of unburned carbon as the carbon in the fly ash was approximately twice that of the optimized TFS 2000TM system.

Engineering and Economic Analysis

An engineering and economic analysis was performed for 3 tangentially-fired utility boilers in the U.S.: a 400MW unit on the East coast firing a low sulfur compliance coal (hvb), a 500MW unit in the Midwestern U.S. firing a local bituminous coal (hvb), and a 330MW unit in the Western U.S. firing a sub-bituminous coal from the Powder River Basin (PRB). The NO_x reduction strategies analyzed included: buying NO_x credits, TFS 2000TM firing system, Ultra-Low NO_x firing system, SCR, and fuel switch to PRB coal.

Boiler performance was modeled using a proprietary ALSTOM Power code to evaluate the impact of firing system modifications on the net plant heat rate and net electric output and to determine the scope of heat transfer surface modifications that may be required. Budgetary pricing of the hardware modifications for the various cases was input into an ALSTOM Power economic model.

As might be expected, the “best” NO_x reduction strategy is unit specific. The Ultra-Low NO_x firing system is the recommended option for the unit firing the PRB coal as firing system modifications alone can achieve the 0.15 lb/MMBtu emissions target. Fuel switching to PRB, along with the Ultra-Low NO_x firing system is the most attractive option for the Midwestern unit, while the economics for the East coast unit are very dependent upon the price of NO_x credits and PRB fuel.